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THE EFFECTS OF PERT ON R&D ORGANIZATIONS*

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INTRODUCTION

This study, which is part of a larger study of project management, (Marquis and Straight, [3]; Rubin and Marquis [7]; Rubin [6]) was carried out to investigate the effects of Program Evaluation and Review Technique (PERT) on large R&D organizations. Since PERT is primarily a scheduling system, prior research has focused on its effectiveness in solving scheduling problems; (see, for example, [4]) in addition, there has been some research concerning management use and acceptance of PERT. Hayya, (Hayya [1]) for instance, has done an exhaustive study on the implementation of PERT by the Department of Defense. There was, apparently, much bitterness generated as a result of this implementation, but as Hayya suggests "Much of the friction between the government and the aerospace industry attributed to PERT is really due to the older, more subtle and extremely more complex marriage between the defense establishment and the aerospace industry". (Hayya, 1966, pages 2-3) Hayya derives a decision model, based upon variables such as type and size of contract, by means of which a procurement manager may decide to require the use of PERT. Although this type of research is extremely valuable, it does leave some questions unanswered.

For example, Hilton, (Hilton, [2]) in a study of seven companies not primarily engaged in Research and Development found that as far as the individual companies were concerned the reason for using PERT is not always solely to improve scheduling: "The most frequently cited advantage was not savings in cost or time but rather improved communications and cooperation between groups involved in a project". (Hilton, 1966, pages 28) Hilton also notes at this point that the improved communications are often due to the fact that in order to set up the PERT chart the man in charge of the project must become familiar with all stages of the job, and that in the planning meetings before the job begins the individuals in charge of the various subactivities become acquainted with each other's problems. Convincing people in an organization that PERT can be helpful is also a problem: "Introducing the method often required a soft sell, and most firms agree that it takes up to five years to obtain complete acceptance." (Hilton, 1966, pages 32)

Poust, in a study of large scale government sponsored R&D projects (Poust and Rubin, [5]) has pointed out an interesting anomaly in the roles of the project manager and the lab manager. They were asked to list the most important problems facing a person in their position. They were also asked to estimate how they spent their time on the project under investigation across a series of comparable problem areas. Neither the project nor the lab managers spend their time on those problems which they consider to be generally most important. For example, although across the sample of projects studied they both spend most of their time fighting "fires", (technical, cost, and schedule), the project manager considers finding methods of controlling these problems by far the most important aspect of his job while the lab manager thinks that finding and keeping competent people and providing motivation for those currently working on projects are the most important aspect of his job.

In the light of these kinds of evidence it is reasonable to ask several kinds of questions about what the introduction of PERT will do to an R&D organization. Will the use of PERT create conditions favorable to better communications? Will there be resistance to its use? Will the use of PERT cause changes in authority structures that will tend to bring the actual problem structures which the lab manager and project manager face more in line with the ones which they consider to be generally most important? In addition to these organizational issues, questions regarding the impact of utilizing PERT on project performance will also be examined.

METHOD

Sample Characteristics

A project was selected in a company or a government agency on two criteria: (1) random or most recently completed, and (2) more than $1 million in size. The projects were contracted by twelve government agencies. The firms studied are all in the aerospace and electronics industries, and 80 percent of them are among the 100 largest performers of government-funded R&D. They are located in all parts of the country.

The projects ranged in size from $1 million to $60 million with a median of $4 million. The average project duration was 3.4 years and none lasted more than 6 years. Almost all of the projects required advances in the "state of the art" in a technological field such as advanced radar systems, microminiaturization of electronics modules, electronic data processing interfaces with telemetry systems, etc. The projects studied are more developmental than fundamental research.

Information on each project was obtained from five sources: the laboratory manager (LM), the project manager (PM), the government technical monitor (GTM), the government contract administrator (GCA), and the company contract administrator (CA). Although a total of 48 projects were studied, inevitable difficulties in securing some of the desired information resulted in incomplete records in several cases. In 75% of the cases the records are complete (LM, CA, PM, GTM, and GCA). Incomplete information results primarily from an inability to interview either the LM, GTM, or the GCA. Pert was used on 24 of these projects and other methods such as bar charts, gantt charts and milestone identification were used on 18: scheduling information was not available on the remaining 6.

Cost and Schedule Performance

Information on cost and schedule changes was gathered from the project manager and contract administrator in the company and from the government contract administrator. Careful cross-checking on the reasons for contract changes made it possible to eliminate those caused by a customer's action, such as a change in scope or specifications, or the unavailability of government test equipment or facilities. Thus only those slippages which were directly attributable to the actions of the contractor firm are included. While the data do not at present include the amount of cost and schedule variance, only those greater than 10 percent are included. On this basis there were 28 overruns and 16 on target or underruns. The rank correlation between cost and schedule performance was 0.82, so the two are combined to form a single performance measure.

Technical Performance

It is presently impossible to compare the technical performance of different projects by any objective measures. In one instance, speed may be the primary technical objective of a system (missile, airplane, etc.), while in another case range is most critical. In an electronics system, reliability or maintainability may be the chief goal. Consequently the measure of successful technical performance used in this study are expert judgments by the most fully informed individuals.

Success ratings were obtained independently from the project manager, the laboratory manager, the government contract administrator and the technical monitor. The ratings were on a scale from one to nine, with nine representing an outstanding success and one signifying a failure (in some relative sense, since no project in this study achieved the absolute failure of being cancelled before completion).

The measure of performance used in this study is the average of the ratings provided by the project manager and the government technical monitor, plus a constant term to account for the fact that project managers were consistently more optimistic than technical monitors. All except one of these scores fell in the range of five to nine within which there was a symmetrical distribution with the median at 6.4. For the sample of projects studied, technical performance is unrelated to cost and schedule performance.

Authority Structure

In order to get some idea of the authority structure of the organization, both the LM and the PM were asked a number of questions concerning decision making power in various areas. (See table I)

On any given project there are three levels within the laboratory at which decisions may be made: they may be made by the project manager's subordinates, by the project manager, or by laboratory management. The first of these two are considered within the project area and the latter outside the project area.

Communication

The kind of communication which we are trying to measure is essentially informal rather than formal. That is, we are trying to measure the effectiveness of existing communication links, in particular the PM-LM link, rather than looking at the communication structure. Any such process must, at the present time, be inferential. The method which we have used is to call the LM rating of PM technical performance and informal communication measure. More specifically, we expect that on those projects using PERT, a LM will think that his PM is doing a superior job. This feeling on the part of the LM will be independent of how well the PM is actually doing.

This expectation rests upon the assumption, substantiated by Hilton's work mentioned earlier, that the LM and PM will better understand each other's problems as a result of the planning meetings associated with the utilization of PERT.

Table 1

Decision Level Questions Asked of
Project Manager and Laboratory Manager

Who in the Organization Made the Following Decisions for this Project?	PM'S SUBORDINATES	PM	HIGHER
1. Authorization of total overtime budget			
2. Contract change in schedule or cost			
3. Authorization to exceed company funding			
4. Exceed approved personnel rushing for crashing project			
5. Initiation of work in support areas			
6. Assign priority of work in support areas			
7. Change schedules for project subactivities			
8. Make versus buy (whether to subcontract)			
9. Select subcontractors			
10. Select sources of supply (off shelf items)			
11. Hire additional people			
12. Contract change in technical scope (or content)			
13. Bring subcontracted work in-house			
14. Authorize subcontractors to exceed cost or schedule			
15. Authorize subcontractor to reduce technical content			
16. Omit tests			
17. Relax performance requirements			
18. Create additional concurrent schedules			

RESULTS

The analysis procedure was to use the 18 projects which did not use PERT as a "control" group and compare them with the 24 which did.[1] In order to control for any contaminating influences in the analysis, the data were first checked to see if the results were due to any obviously exogenous sources. The first two sources which were checked were dollar size and degree of haste i.e., whether or not it was a crash program. The reason for checking these two particular areas is

Table II

Utilization of PERT vs. Dollar Size of Project

\$ SIZE/10^6	NUMBER OF PROJECTS	NUMBER OF PERT PROJECTS	% PERT
1	5	3	60%
2	6	2	33%
3-4 (INCL.)	8	4	50%
6-10 (INCL.)	6	4	66%
>10	6	3	50%
	31	15	

Fisher Exact (SPLIT ON MEDIAN) $<.41$

[1] Throughout the analysis a significance level of .05 (one tail) was used.

Table III

PERT vs. Crash Programs

	PERT	NON PERT
CRASH	34%	59%
NON CRASH	66%	41%
	N=26	N=17

FISHER EXACT $<.15$

that either of these factors may well affect the internal priority which the organization gives to the project. Rubin (Rubin, [6]) has found that technical performance is critically sensitive to internal priority. However, it is readily obvious (see tables II and III) that PERT is not particularly associated with either high or low project dollar value or crash or non-crash priority. The other variable which we controlled for was the date the project started. To understand the necessity for checking this variable we must view the historical perspective both of the data and of the use of PERT. The time span of the data, 1957 to 1963, coincides roughly with the period of time during which PERT was introduced. If it happened that all of our PERT projects had begun, say, in the last 3 years, then our results could be open to the interpretation that the effects are due to a time displacement rather than to PERT itself. However this is not the case. (see Table IV)

Table IV

Utilization of PERT vs. Year Project Started

YEAR	NUMBER OF PROJECTS STARTED	% PERT PROJECTS
1957	1	0%
1958	2	50%
1960	5	40%
1961	12	58%
1962	7	57%
1963	9	67%

Pert vs. Performance

There is no significant difference in technical performance between projects which used PERT and those which didn't. (See Table V)

Table V

Relation Between PERT and Technical Performance

		PERT	NON PERT
TECHNICAL PERFORMANCE	% GREATER THAN OR EQUAL TO MEDIAN	56%	59%
	% LESS THAN MEDIAN	44%	41%
		N=24	N=18

MANN WHITNEY U NOT SIGNIFICANT

There is however, a significant difference in cost/schedule performance between those projects which use PERT and those which do not. (Table VI) Pert projects do better in cost and schedule performance than do non-pert projects. This will not come as a great shock to those who have previously believed in PERT as a scheduling tool.

Table VI

Relation Between PERT and Schedule Performance

	PERT	NON PERT
% OVERRUNS	42%	67%
% NON OVERRUNS	58%	33%
	N=20	N=16

FISHER EXACT PROBABILITY $<.05$

<u>Pert vs. Authority Structure</u>

As might be expected, it is more difficult to determine differences in authority structure than it is to find differences in technical and cost/schedule performance. The approach we used here was to compare the lab managers' responses to the decision level question (see Table I) on PERT projects to the responses on non-PERT project. There were five significant differences. (see Table VII). For example, the LM is much more likely to think he has the authority to change schedules for project subactivities if he is working on a PERT project than he is if he is working on a non-PERT project.

Table VII

Lab Manager Perceived Authority Structure on PERT Projects

DECISION AREA	AUTHORITY LEVEL IS:	
	IN THE PROJECT AREA	OUTSIDE THE PROJECT AREA
ESTABLISH PRIORITY	*	
AUTHORIZE OVERTIME BUDGET	*	
MAKE THE DECISION TO SUBCONTRACT	*	
INITIATE WORK IN A SUPPORT AREA		*
CHANGE SCHEDULES FOR PROJECT SUBACTIVITIES		*

As was mentioned previously, "in the project area" means either with the project manager or his subordinates; "outside the project area" means with the lab manager. As a check on the results, the answers which the PM gave to the same question were also checked. In all cases except one, there was agreement: the exception was "establish priority." In this instance, each thought that the other had authority in this area.

Communication

The informal communication measure which we have used is LM rating of PM technical performance. As anticipated the lab managers on PERT projects give considerably better performance ratings to their project managers than do those on non-PERT projects. (See Table VIII) Validation

Table VIII

Lab Manager Rating of Project Manager Performance vs. PERT

	PERT	NON PERT
% RECEIVING EXCELLENT RATING	61%	29%
% RECEIVING LESS THAN EXCELLENT RATING	39%	71%
	N=23	N=17

FISHER EXACT $< .05$

of the assumption is done by comparing the LM rating of PM technical performance with actual project performance. The results are that in fact the LM rating is not related to actual project performance. (Table IX)

As was mentioned previously, the process of informal communication measurement must be inferential. The inference which we draw from this somewhat surprising result is that when the LM answered this question he was not thinking about how well the PM actually performed technically, but how well he (the LM) could relate to the research process through the PM, and this is a measure of communication. The lab manager's rating of the project manager's administrative ability was unrelated to actual cost and schedule performance which further strengthens this argument.

Table IX

Tech Performance vs. LM Rating of PM Tech Performance

		LM RATING OF EXCELLENT	LM RATING OF LESS THAN EXCELLENT
TECHNICAL	% GREATER THAN (OR EQUAL TO) MEDIAN	42%	52%
PERFORMANCE	% LESS THAN MEDIAN	58%	48%
		N=19	N=21

MANN WHITNEY U NOT SIGNIFICANT

CONCLUSIONS AND DISCUSSION

There are two definite conclusions which can be drawn from the results. First, PERT does lead to improvement of schedule performance and secondly, it does so without any noticeable effect on technical performance. The other results shed some light on how projects that use PERT differ from those that do not, and provide some basis for speculating on how the improvement is achieved.

The improvement in communication with the use of PERT is indicative of an increase in lab manager visibility to the project manager. And visa versa it is interesting to note that the areas in which the LM is more visible, <u>i.e.</u>, in initiating work and changing schedules, both lie in the scheduling domain. In other words, the improved communication is channeled into the scheduling function rather than, say, the technical area. This kind of organization is logical from a motivational viewpoint because the lab manager is probably more concerned with scheduling than is the project manager. PERT enables the lab manager to communicate his concerns to the project manager.

In this light, the establishment of priority conflict is rather interesting. (As noted before the LM and PM each think that the other has this authority.) If, as we have surmised, the LM has moved into the scheduling area, he subsequently ought also to have some control over priority. However, the relationship between priority and completion is not direct, and it is possible that the lab manager is pushing hard enough in this area so that the PM feels that the LM has the authority although the LM is not quite ready to admit that he is determining priorities. While "gaining" authority in the scheduling area, the LM cedes some in the areas of subcontracting and overtime budget. This may be a political move to keep the PM happy, or it may be that the LM simply does not have time to do both. However, the net effect allows the PM two more tools with which to solve the technical and cost "fires". Combining this information with Poust's study, we find that this shift brings the project manager's job closer to the way in which he actually perceives it.

In summary, using PERT does lead to better cost/schedule performance but has no effect on technical performance. However, we suspect that the reason for the improvement in scheduling performance lies not in the fact that PERT is a better scheduling technique, but that it provides a method by which the person in the organization who is concerned with scheduling (in this case, the LM) can gain authority in this area.

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